# Cascadia Hazards Communications, Preparedness: Needs and Charge for a NEPEC Subcommittee

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NEPEC

3 Nov 2010

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## Challenge:

- How can we use our knowledge of earthquakes together with burgeoning data streams to provide the most accurate and useful information to emergency managers and to the public in the event of heightened activity in Cascadia?

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# Cascadia Megathrust Sequences

- Megathrust rupture unlikely to be a single event
  - M9 (NSHMP 67% weight) will have aftershocks, likely including M8 earthquakes months/years later
  - Several events M8-8.7 (NSHMP 33% weight), temporal evolution of sequence unknown
- Indicators that Cascadia event sizes vary:
  - Turbidite studies (Goldfinger et al.) indicate more events, shorter recurrence intervals (220 years) southern Oregon
  - Nelson et al. (various paleo indicators) find evidence for shorter recurrence intervals in southern Oregon
  - Tremor-slip events in southern Oregon recur more often and seem to represent less slip than northern Cascadia ETS events

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# Cascadia Policy Challenges

- 3 states, 2 countries involved
- State emergency management agencies (and FEMA) unprepared to receive "advisory" information
  - OR and WA have no experience with earthquake "advisories"
  - CA seems less prepared to use advisory information than in the past
- Many organizations collect, monitor data, but synthesis not routine
  - Earthquake monitoring by PNSN, NCSN, and national network
  - Tremor detection & location - UW, GSC
  - GPS (PBO, other operators, CWU analysis)
  - Strain (PBO data, USGS analysis)
- Advisories could potentially arise from
  - Potential foreshocks
  - Accelerated aseismic slip - very little basis for evaluation
- Emphasis is on "The Big One" - whereas a Cascadia megathrust sequence might very well include more than one event of M>8

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# Where we are now (Nov 2010)

- CA, OR and WA, and BC Emergency Managers and Geological Surveys are aware of issues, eager to plan
  - However, OR, WA, and BC EM's mainly focused on response to damaging event, not anticipatory advisory-type information
- FEMA: not involved yet
- USGS: monitoring enhancements
  - Software to visualize diverse data types/ ARRA funding (in progress)
  - Need: Protocols for communication among non-USGS monitoring groups (probably easier after software development further along)
- NEPEC: appoint subcommittee of regional experts -?
  - Deal with Cascadia subduction earthquakes, not all events within OR and WA (PNSN handles those)
  - Standing subcommittee, or disbands after several meetings?

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# Tasks that need doing soon:

- Develop comprehensive set of plausible possibilities for Cascadia sequences
  - Seismic sequences (foreshocks, aftershocks,other)
  - aseismic events
- Evaluate the degree to which we can quantify time-dependent short-term probability of a damaging earthquake based on potential foreshocks or anomalous aseismic events
  - Decide what data and analyses would be helpful in real time
  - Call attention to research and monitoring needs
- Written statements, prepared with EM input:
  - Statements for automatic release (example next)
  - Templates for rapid release

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# Cascadia Foreshock Issues

- Available data insufficient for robust statistics
- Current seismicity seemingly unrepresentative
  - Very little offshore coverage
    - NSF Cascadia-MARGINS will fund OBS's, but no real-time data from them
- Limited ability to resolve exact nature of event
  - Depth to subducting slab uncertain in Oregon
  - Network coverage poor in southern Oregon

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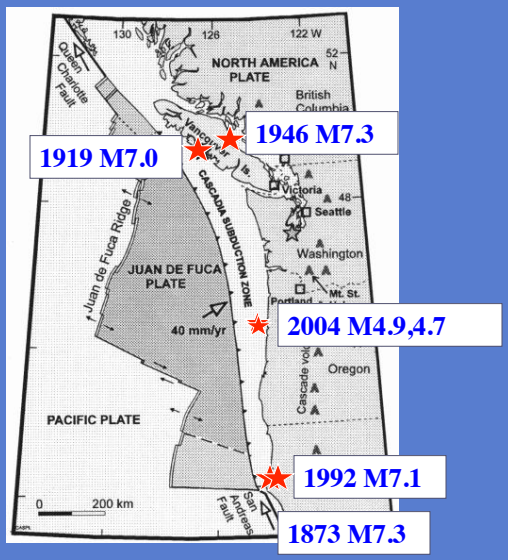
# Cascadia Subduction Interface Seismicity




Pacific Geoscience Center, updated by ER

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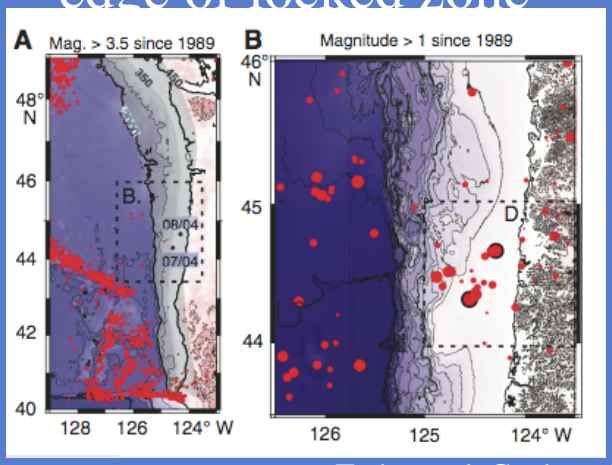
# Interface events (M<=4.7) at downdip edge of locked zone




Trehu et al. Geology 2008

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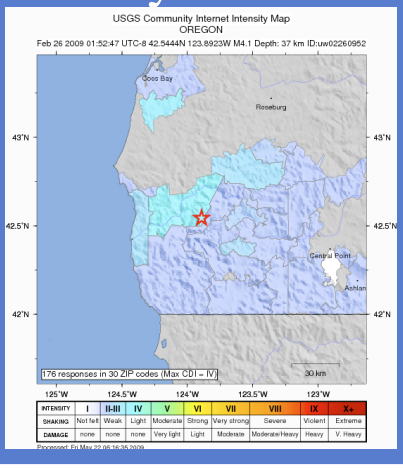
# M4.1 Southern Oregon February 26 2009





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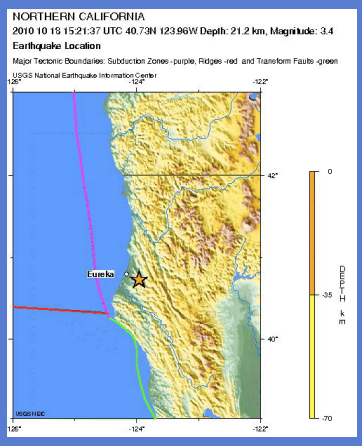
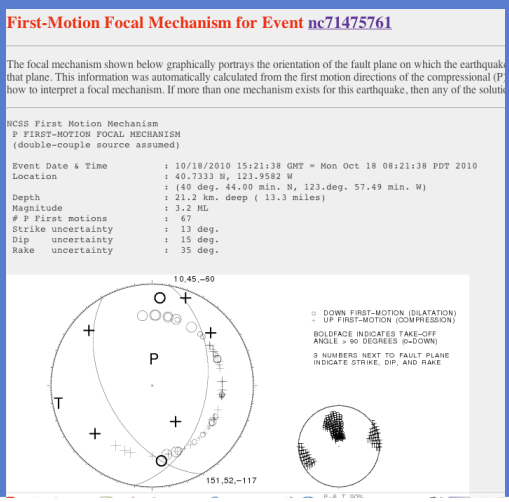
# Oct 18 2010 - on Subduction interface?

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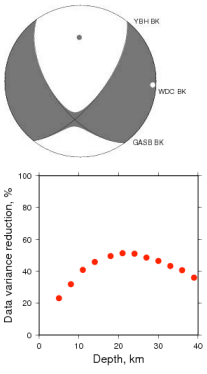
# Oct 18 2010 N Ca event

**NCSS Moment Tensor Solution**

**Solution reviewed by Taka Taira**




Hypocentral Location:

| | |
|---|---|
| Event ID | 71475761 |
| Origin Time | 2010/10/18 15:21:38 |
| Latitude | 40.7333 |
| Longitude | -123.9582 |
| Depth (TT) | 21.2 km |
| Depth (MT; not authoritative) | 21 km |

Magnitudes:

Md 3.4 (not authoritative)
Ml 3.2 (not authoritative)
Mw 3.43 (authoritative)

Deviatoric Solution:

Scale 10**21 Dyne-cm

| Axis | Value | Plunge | Azimuth |
|---|---|---|---|
| T | 1.748 | 5 | 93 |
| N | 0.037 | 48 | 188 |
| P | -1.785 | 42 | 358 |

Source Composition:

| Type | Percent |
|---|---|
| DC | 96 |
| CLVD | 4 |
| Iso | (null) |

Moment Tensor:

| | |
|---|---|
| Moment | 1.77e+21 Dyne-cm |
| Scale | 1.0e+21 Dyne-cm |
| Mxx | -0.969 |
| Mxy | -0.062 |
| Mxz | -0.913 |
| Myy | 1.730 |
| Myz | 0.169 |
| Mzz | -0.761 |
| Variance Reduction | 51% |
| Version number | 1 |
| Solution time | 2010/10/18 22:21:03 UTC |

Best-fit Double Couple Solution

| Plane | Strike | Rake | Dip |
|---|---|---|---|
| NP1 | 38 | -36 | 66 |
| NP2 | 145 | -151 | 58 |

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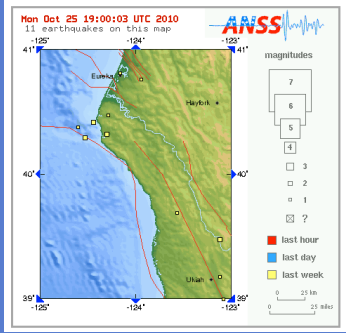
# ANSS earthquakes within last 7 days as of 1900 UTC on 10/25




## Earthquake List for Map Centered at 40°N, 124°W

**Update time = Mon Oct 25 19:00:05 UTC 2010**

Here are the earthquakes in the Map Centered at 40°N, 124°W area, most recent at the top.
(Some early events may be obscured by later ones.)
Click on the underlined portion of an earthquake record in the list below for more information.

| | MAG | UTC DATE-TIME y/m/d h:m:s | LAT deg | LON deg | DEPTH km | LOCATION |
|---|---|---|---|---|---|---|
| MAP | 1.7 | 2010/10/24 04:09:41 | 39.002 | -123.086 | 1.8 | 15 km ( 9 mi) WSW of Lakeport, CA |
| MAP | 2.3 | 2010/10/23 16:58:55 | 40.326 | -124.308 | 11.6 | 2 km ( 1 mi) W of Petrolia, CA |
| MAP | 1.5 | 2010/10/22 14:05:26 | 40.474 | -124.295 | 21.1 | 12 km ( 7 mi) SSW of Ferndale, CA |
| MAP | 1.9 | 2010/10/22 11:25:16 | 40.761 | -123.945 | 23.0 | 14 km ( 9 mi) SSE of Blue Lake, CA |
| MAP | 1.7 | 2010/10/22 07:11:04 | 40.379 | -124.612 | 23.2 | 28 km ( 18 mi) WNW of Petrolia, CA |
| MAP | 2.0 | 2010/10/22 05:11:40 | 40.296 | -124.538 | 19.9 | 22 km ( 13 mi) W of Petrolia, CA |
| MAP | 1.9 | 2010/10/20 11:45:24 | 40.816 | -124.172 | 2.5 | 3 km ( 2 mi) NNW of Eureka, CA |
| MAP | 2.0 | 2010/10/20 05:06:59 | 39.481 | -123.125 | 3.5 | 16 km ( 10 mi) WNW of Lake Pillsbury, CA |
| MAP | 2.0 | 2010/10/20 00:25:09 | 40.422 | -124.450 | 19.7 | 18 km ( 11 mi) NW of Petrolia, CA |
| MAP | 1.5 | 2010/10/18 22:38:10 | 39.692 | -123.573 | 6.7 | 7 km ( 5 mi) WNW of Laytonville, CA |
| MAP | 1.4 | 2010/10/18 21:39:43 | 39.181 | -123.123 | 2.7 | 6 km ( 4 mi) NNE of Talmage, CA |

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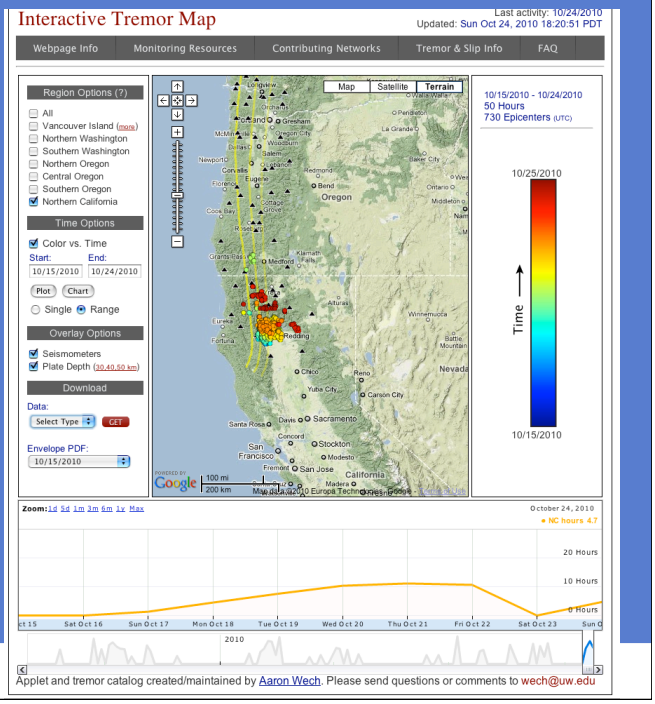
Back to Map Centered at 40°N, 124°W

# Tremor map 15 thru 24 Oct

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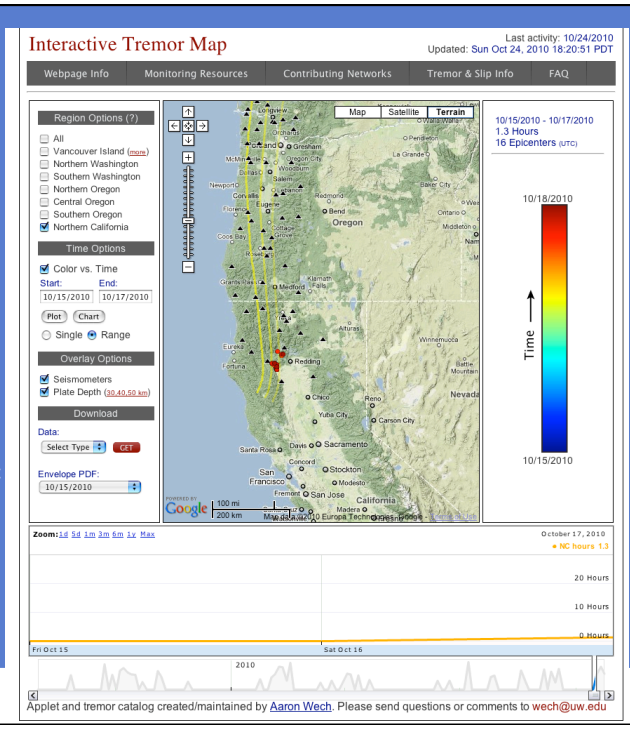
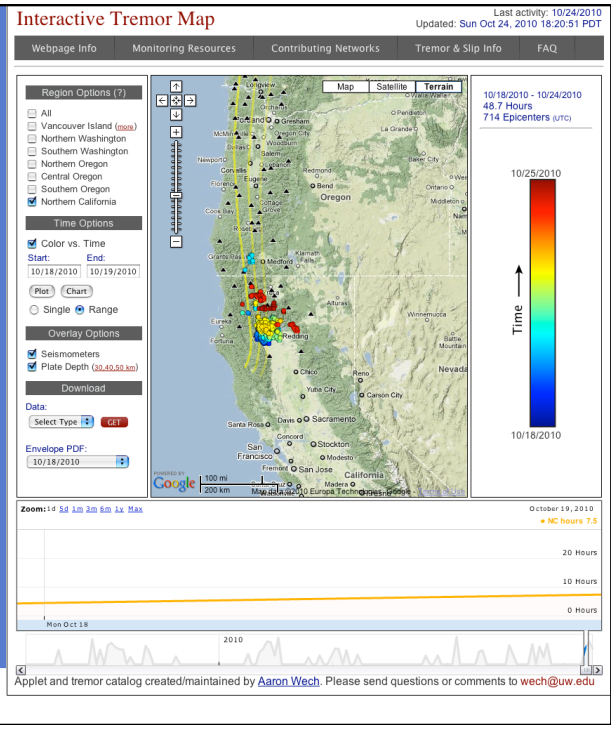
# Tremor map 15 thru18 October

First event returned from request for 15 Oct to 24 Oct:

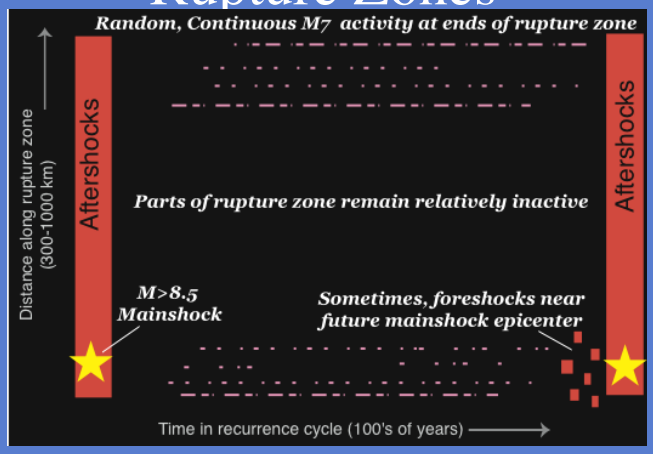
2010-10-17 11:15:00, 40.780,122.750 NC




# Tremor map 18 thru 24 October



# Seismicity of Great Earthquake Rupture Zones




- Earthquakes >M8.5 worldwide show a seismicity pattern that sometimes includes foreshock activity (Perez and Scholz, JGR,1997)

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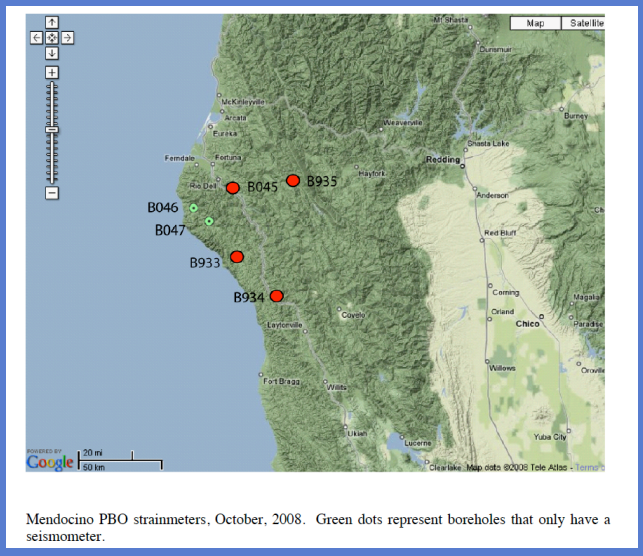


Mendocino PBO strainmeters, October, 2008. Green dots represent boreholes that only have a seismometer.

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# Aseismic Deformation: "ETS"

- Published papers argue for aseismic slip preceding
  - 1960 Chile earthquake (apparently not for 2010 Chile EQ)
  - 1944 M8.1 Tonankai earthquake (basis for Tokai Prediction Expt)
- Modeling studies imply changes in intervals between, updip extent, and amount of slip during episodic slip events
- Northern Cascadia ETS events seem to be "business as usual"
  - They undoubtedly transfer stress to the locked zone
  - But probability increase of typical event is small
- What about aseismic deformation that differs from "business as usual"?
  - Updip, ie, closer to locked zone
  - Much larger

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# Approaches to getting probabilities from ETS geodetic data:

- Tokai approach: does geodetic data from slow slip event indicate slip near anticipated hypocenter of next great Tokai EQ?
  - We don't have an idea of the hypocenter of the next Cascadia EQ.
- Parkfield approach: what is distribution of particular anomaly size in the record from the instruments?
- Cascadia approach(??): Keep recording and comparing events, build up knowledge of how much "background" events vary

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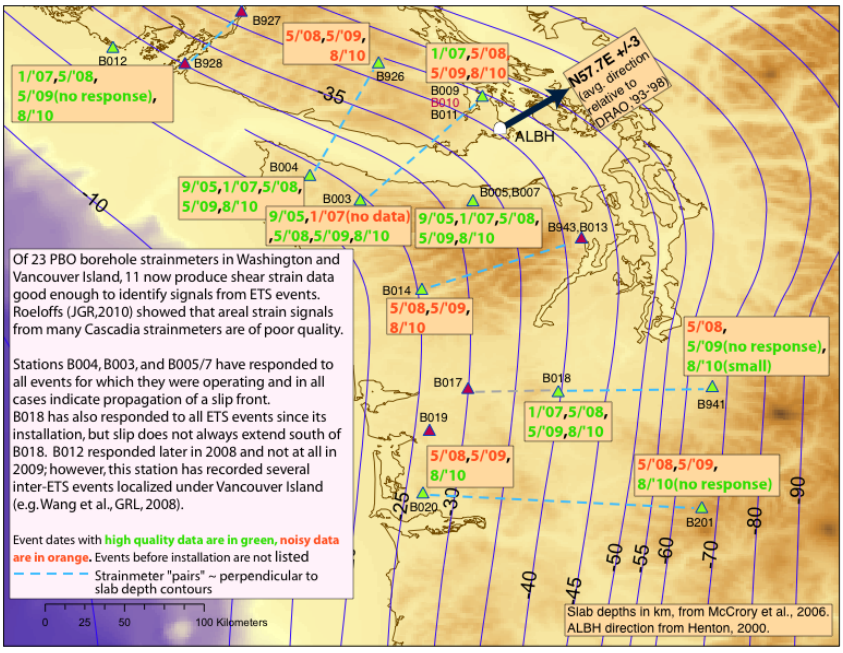


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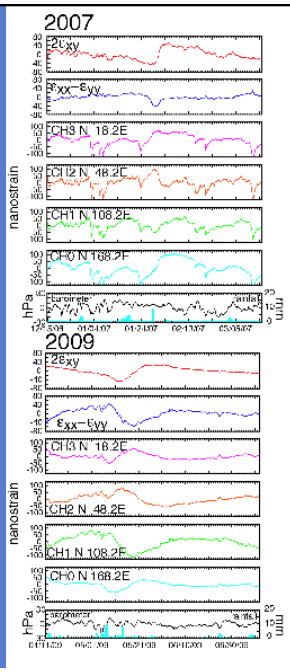


## Four ETS events at PBO Borehole strainmeter B004 on the northern Olympic Peninsula

Strains are in coords with x parallel to CH1 (N108E) to avoid any uncertainty about orientation.

Data have been detrended; tides and barometer removed; isotropic coupling matrix used.

Areal strains are noisy and are not shown.

Note:
-Events have similar time histories but time scales differ
-Almost all strain excursions are close to the same amplitude
-Less event-to-event similarity at northern and southern ends of the zone of ETS events (not shown).

Significance:
-Could probably identify an "anomalous" event despite difficulties of calibrating strainmeters

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# Tasks that need doing soon:

- Develop comprehensive set of plausible possibilities for Cascadia sequences
  - Seismic sequences (foreshocks, aftershocks,other)
  - aseismic events
- Evaluate the degree to which we can quantify time-dependent short-term probability of a damaging earthquake based on potential foreshocks or anomalous aseismic events
  - Decide what data and analyses would be helpful in real time
  - Call attention to research and monitoring needs
- Written statements, prepared with EM input:
  - Statements for automatic release (example next)
  - Templates for rapid release

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# Many groups need to be represented
## (or at least feel heard)

- All 3 states, 2 countries involved
- FEMA, Canadian Hazards agency
- NOAA Tsunami Hazard Program
- State and provincial emergency management agencies
- USGS, GSC
- State geological surveys
- Organizations collecting/monitoring data
  - Earthquake monitoring: PNSN, NCSN, ANSS
  - Tremor detection & location - UW, GSC
  - GPS (PBO, other operators, CWU analysis)
  - Strain (PBO data, USGS analysis)
  - OBS data (U of O, NSF)
  - SOSUS data (NOAA PMEL)
- Hazards/Social Science community
- **Earthquake scientists in region**
- **Earthquake scientists doing related research**

~20 groups

All of whom seem to bring needed information

Adds ~10 more people

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## To manage large group:

- Appoint small (5-8) member NEPEC subcommittee
  - Defines questions and problems
  - One question is, *whether a standing subcommittee is needed*
- Convene representatives of all interested groups in one workshop* to address those questions
- Small subcommittee summarizes workshop results and plan
- Plan circulated to larger group
- Plan "finalized" by NEPEC subcommitee
- ….but will require periodic updating as more information becomes available (5-6 year intervals?)

**Funding source for such a workshop needs to be identified*

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## When an event occurs: Info needed ***to evaluate likely evolution of activity*** (NEPEC's job)

- Detection and characterization
  - Some automatic and fast (eq locations, some moment tensors)
  - Some quick, but require human interaction (moment tensors, depths)
  - Some characterization done later on research basis
- Communication to outside world, promoting one unified message
  - Automatic: Noncontroversial "facts"
  - Pre-agreed templates to be filled in based on quick analyses and prompt conference among experts
  - Advisories? Do we know enough?
- Enhanced monitoring and data collection
- Detailed interpretation by "experts": standing NEPEC subcommittee??
- *…."awakening" of Cascadia could initiate a long period of intensified vigilance*

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# Possible wording of a message that could be released automatically

**The __th ____ 20xx, M6.x Earthquake Located on or near the Locked Zone of the Cascadia Subduction Megathrust**

**Spokespeople TBD, but including representatives from USGS, DOGAMI, WA Geological Survey , Geological Survey of Canada… etc.**

**Version 0.0, by E. Roeloffs, USGS, for comment.**

A M6.? earthquake has occurred offshore? California? Oregon? Washington? British Colmbia? (give distances to nearest cities…). Seismologists expect aftershock activity to continue for many days, and remind everyone that large aftershocks can take place after days or even weeks have elapsed.

**This earthquake is significant because it occurred on or near the Locked Zone of the Cascadia Subduction Megathrust. The earthquake exhibited motion of the oceanic plate to the ??east, consistent with subduction of the oceanic plate under North America. In the last 50 years, there have been no other subduction earthquakes with magnitude >6 within 100? km of this location. The most recent earthquake of M>6 on the Cascadia subduction fault was the 1992 M7.1 Cape Mendocino earthquake.**

*Continues….*

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## *Possible Automatic message, continued*

**Earthquake scientists at USGS and academic institutions recognize that this earthquake warrants special attention and will heighten public concern. We remind the public that the Cascadia Subduction Zone is capable of producing very large earthquakes, accompanied by highly destructive tsunamis. It is the plate boundary that accommodates about 1.5 inches/year of motion as the oceanic tectonic plates move under the North American plate, and it extends for more than 500 miles from Cape Mendocino, in northern California, to central Vancouver Island, British Columbia. Geologic evidence shows that the Cascadia Subduction Zone has produced earthquakes of magnitude 8.5 to 9 at intervals of 300 to 500 years, accompanied by dangerous tsunamis, with the last such event having occurred in 1700.**

**The USGS estimates that there is approximately a 14% chance of a M8 or greater Cascadia Subduction earthquake before 2060. The occurrence of today's M6.? earthquake on the Cascadia Subduction Zone and its continued aftershocks represents a period of greater earthquake activity in this part of the subduction zone than has been observed in the last 50 years. Although our record of Cascadia seismicity is too sparse to calculate precise statistics, such calculations for other regions show that the likelihood of an earthquake being followed by a larger event is elevated over the background rate for a period of 3 to 10 days.**

*Continues….*

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## *Possible Automatic message, end*

**Earthquake scientists at USGS, PNSN, and UC Berkeley are on 24-hour duty monitoring the Cascadia subduction zone using seismometers, more than 100 precise high-rate streaming GPS stations, and 35 borehole strainmeters, and emergency management officials have planned what actions they will take and recommend if any developments raise our level of concern (give website of response plan?). We will be able to judge whether the aftershock activity and afterslip from today's earthquake are gradually declining, as would be expected for the mainshock of a seismic sequence. However, we have no tested methodology for determining whether today's M6+ earthquake might be a foreshock, nor do we know of any other certain signs that could allow us to predict a larger event. *If you are in a location potentially impacted by a major Cascadia earthquake, do not plan on advance warning and do not delay taking measures to ensure the safety of yourself and those who depend on you.***

**Residents in areas expected to be impacted by a major Cascadia earthquake should immediately review their earthquake preparedness plans. Coastal residents are urged to continue to follow the advice to head for safe ground to avoid possible tsunami hazard whenever they feel shaking, despite the inconvenience that may be caused by shaking from aftershocks in the next days to weeks.**

**For additional information check (website) Press releases will be issued at least daily for the next two weeks, and immediately if observations raise our level of concern.**

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# Suggested Members/Specialties

(in addition to NEPEC members , local USGS scientists)

- Herb Dragert, Geological Survey of Canada
- Takeshi Sagiya, Geographical Survey Inst (subduction zone geodetic monitoring in Japan)
- Kerry Sieh (paleoseismology, subduction sequences)
- Hiroo Kanamori (Chile earthquake)
- Lori Dengler (Northern CA hazards)
- State Geological Surveys (1 rep from each state)
- Steve Kirby (subduction zone physics)
- Expert analyst of seismic signals from very large events (Doug Dreger?)
- John Pallister - volcano connection; experience with real-time responses to volcanic crises

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